

## CLAIMS

What is claimed is:

1. A system for creating bubbles on demand for use within a medium administrable to a patient for purposes of a medical procedure, said system comprising:

5 (a) a reservoir for storing a liquid;

(b) a pressurizing device for conveying the liquid, and the medium formed therewith, through said system;

(c) a bubble generator for creating the bubbles of gas within the liquid to form the medium, said bubble generator having an inlet for receiving the liquid and an outlet for  
10 communication of the medium to the patient; and

(d) a controller for controlling operation of said system so that the bubbles created by said bubble generator are generated according to the demands of the medical procedure and are administrable within the medium to the patient.

15 2. The system of claim 1 wherein said pressurizing device includes at least one of a gear pump, a peristaltic pump, a syringe pump and a centrifugal pump.

3. The system of claim 1 wherein said controller controls at least one operating parameter of said pressurizing device and said bubble generator.

20

4. The system of claim 1 wherein said controller controls at least one operating parameter of said system based at least in part on feedback from an imaging unit used during the medical procedure.

5. The system of claim 1 wherein said controller includes a user interface for at least one of monitoring and changing at least one operating parameter of said system.

6. The system of claims 3, 4, or 5 wherein said operating parameters of said system include composition of the medium, composition of the bubbles in the medium, concentration of the bubbles in the medium, size of the bubbles in the medium, rate of flow of the medium, volume of the medium administered, timing of the administration of the medium, sequencing of the administration of the medium, pressure of the medium, and temperature of the medium.

7. The system of claim 1 further comprising a fluid verification device disposed between said bubble generator and the patient, said fluid verification device for at least one of monitoring and changing at least one operating parameter of said system.

8. The system of claim 7 wherein said fluid verification device is capable of at least one of (i) detecting an unacceptably large amount of the gas and preventing administration thereof to the patient and (ii) destroying any of the bubbles having a diameter at least one of greater than, less than, within, and outside a predetermined range of sizes.

9. The system of claim 7 wherein said controller at least one of communicates with and controls operation of said fluid verification device.

10. The system of claim 7 wherein said controller controls operation of said system based at least in part on information from said fluid verification device.

11. The system of claim 1 wherein said bubble generator creates the bubbles by entraining the gas from a source thereof into a flow of the liquid to form the medium.

12. The system of claim 11 further comprising a fluid verification device disposed between said bubble generator and the patient, said fluid verification device for preventing administration of the medium upon at least one of a rate of flow of the medium dropping below a specified level and detecting that the medium contains an unacceptably large amount of the gas.

13. The system of claim 1 wherein said bubble generator comprises:

- (a) an enclosure within which to agitate the liquid in presence of the gas; and
- (b) a means for disrupting an interface between the liquid and the gas, said disrupting means being responsive to a control signal from said controller by agitating said interface thereby creating the bubbles of the gas within the liquid.

14. The system of claim 1 wherein said bubble generator comprises:

- (a) an enclosure within which to agitate the liquid in presence of the gas;
- (b) a mechanism for agitating associated with said enclosure, said mechanism being responsive to a control signal from said controller by agitating an interface between the liquid and the gas thereby creating the bubbles of the gas within the liquid; and

- (c) a filter disposed proximate said outlet for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

15. The system of claim 1 wherein said bubble generator comprises:

- (a) an enclosure within which to place the liquid in presence of the gas;

(b) two disks disposed in said enclosure, said disks separated by a gap of a preset thickness and capable of being spun;

(c) a mechanism for spinning said disks, said mechanism being responsive to a control signal from said controller by spinning said disks thereby compelling the liquid to flow  
5 into said gap resulting in creation of the bubbles of the gas within the liquid; and

(d) a filter disposed proximate said outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

16. The system of claim 1 wherein said bubble generator comprises:

10 (a) an enclosure within which to place the liquid in presence of the gas;

(b) a stirring element disposed in said enclosure;

(c) a mechanism for moving said stirring element, said mechanism being responsive to a control signal from said controller by moving said stirring element thereby causing the creation of the bubbles of the gas in the liquid; and

15 (d) a filter disposed proximate said outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

17. The system of claim 16 wherein said stirring element comprises multiple small wires.

20 18. The system of claim 1 wherein the liquid is supersaturated with the gas under pressure and has nucleation materials therein, with said bubble generator comprising a nozzle such that as the liquid passes therethrough the pressure of the liquid decreases causing the bubbles of the gas to form on the nucleation materials and come out of and entrain with the  
25 liquid, thereby forming the medium.

19. The system of claim 18 wherein the nucleation materials comprise at least one of particles and chemicals.

5 20. The system of claim 1 wherein the liquid is supersaturated with the gas under pressure as the liquid enters said bubble generator, with said bubble generator comprising a nozzle having a plurality of nucleation sites formed therein such that as the liquid passes through said nozzle and contacts at least one of said nucleation sites the pressure of the liquid decreases causing the gas to come out of solution, forming the bubbles that entrain with the  
10 liquid thereby forming the medium.

21. The system of claim 20 wherein said nucleation sites take the form of pits formed in an inner wall of said nozzle.

15 22. The system of claim 20 wherein said nozzle is cylindrical in shape.

23. The system of claim 20 wherein said nozzle comprises plates attached together to form a pipe, with at least one of said plates bearing said nucleation sites.

20 24. The system of claim 1 wherein said bubble generator comprises:

- (a) an enclosure within which to place the liquid in which the gas is dissolved; and
- (b) a device, controlled by said controller, to apply energy to the liquid to create localized regions of gas supersaturation thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

25

25. The system of claim 24 wherein said localized regions of gas supersaturation comprise regions of reduced pressure created by at least one of mechanical motion, an oscillatory pressure component, and an oscillatory flow component.

5           26. The system of claim 1 wherein said bubble generator comprises:  
          (a) an enclosure within which to place the liquid in which a gas is dissolved; and  
          (b) a transmitter for transmitting ultrasonic energy into the liquid to cause cavitation therein thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

10           27. The system of claim 1 wherein said bubble generator comprises:  
          (a) a liquid flow path for receiving the liquid from said pressurizing device; and  
          (b) a gas flow path in communication with a source of the gas for directing the gas received therefrom to said liquid flow path;

15           with said liquid and said gas flow paths constituting a gas-liquid interface assembly such that said liquid flow path channels the liquid received from said pressurizing device to an intersection with said gas flow path to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.

20           28. The system of claim 27 wherein said controller operates said pressurizing device and said source of the gas to produce an oscillatory component to the flow within at least one of the gas flowing in said gas flow path and the liquid flowing in said liquid flow path.

25           29. The system of claim 27 wherein said bubble generator comprises an array of said gas-liquid interface assemblies.

30. The system of claim 27 wherein said bubble generator further comprises a fluid flow path for receiving a second liquid from said pressurizing device and for channeling the second liquid received therefrom into the liquid into which the gas has been entrained, thereby  
5 further forming the medium for communication from said outlet.

31. The system of claim 30 wherein said bubble generator comprises an array of said gas-liquid interfaces.

10 32. The system of claim 1 wherein said bubble generator comprises:

(a) a gas introduction plate having a plurality of gas inlets in communication with a source of the gas; and

(b) a liquid flow path for receiving the liquid from said pressurizing device and for channeling the liquid received therefrom over said gas introduction plate to entrain as the  
15 bubbles the gas emanating from said gas inlets, thereby forming the medium for communication from said outlet.

33. The system of claim 32 wherein said controller operates said pressurizing device and said source of the gas to produce an oscillatory component to the flow within at least one of  
20 the gas flowing in said gas inlets and the liquid flowing in said liquid flow path.

34. The system of claim 32 wherein said bubble generator further comprises a secondary plate disposed a predetermined distance apart from said gas introduction plate between which the liquid is channeled by said liquid flow path, said predetermined distance  
25 being selected to affect a size of the bubbles so entrained.

35. The system of claim 34 wherein said secondary plate has a plurality of gas inlets by which the gas is further so entrained by the liquid flowing in said liquid flow path.

5 36. The system of claim 1 wherein said bubble generator comprises:

(a) a tube having a plurality of gas inlets defined in a wall thereof and one end for receiving the liquid from said pressurizing device, with said gas inlets adapted for communication with a source of the gas;

10 with said tube for channeling the liquid received from said pressurizing device over said gas inlets to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.

37. The system of claim 36 wherein said controller operates at least one of said pressurizing device and said source of the gas to produce an oscillatory component to the flow  
15 of at least one of the liquid and the gas.

38. The system of claim 1 wherein said bubble generator comprises:

(a) a chamber defining a plurality of gas inlets in communication with a source of the gas; and

20 (b) a liquid flow path defined within said chamber;

with said liquid flow path for channeling the liquid received from said pressurizing device to an intersection with said gas inlets to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.



39. The system of claim 38 wherein said controller operates at least one of said pressurizing device and said source of the gas to produce an oscillatory component to the flow of at least one of the liquid and the gas.

5 40. The system of claim 1 wherein said bubble generator comprises:

(a) a first member having outer and inner sides with a plurality of inlet holes extending therebetween, said outer side of said first member for channeling the first liquid over said inlet holes;

10 (b) a second member having inner and outer sides with a plurality of outlet holes extending therebetween, said outer side of said second member for channeling the liquid over said outlet holes, said inner sides of said first and said second members being separated by a gap and arranged so that each of said inlet holes aligns with one of said outlet holes, said gap for channeling the gas between said first and said second members; and

15 (c) a means for generating droplets of the liquid such that each of said droplets is directed through one of said inlet holes, said outlet hole corresponding thereto and the gas present therebetween and into the liquid on said outer side of said second member thereby forming a bubble therefrom within the liquid to form the medium therefrom.

41. The system of claim 1 wherein said bubble generator comprises:

20 (a) a plate having a first surface and a second surface with an inlet hole extending therebetween, said first surface and a wall of said inlet hole being in contact with the liquid; and

(b) a heater in communication with said wall of said inlet hole to form an interface assembly therefrom; such that, upon application of a pulse of energy to said heater, said heater heats the liquid in said inlet hole to form a bubble of gas therefrom, the bubble moving from  
25 said interface assembly into the liquid flowing along said second surface to form the medium therefrom.

42. A system for creating a medium of bubbles on demand for administration to a patient for purposes of a medical procedure, said system comprising:

(a) a primary reservoir for accommodating a first liquid;

5 (b) an additional reservoir for accommodating at least one of a second liquid and a gas;

(c) at least one pressurizing device for conveying the first liquid and at least one of the second liquid and the gas, and the medium formed therewith, through said system;

10 (d) a bubble generator having at least one inlet for receiving the first liquid and at least one of the second liquid and the gas and creating therefrom the medium, said bubble generator having an outlet for communication of the medium to the patient; and

(e) a controller for controlling operation of said system so that the bubbles created by said bubble generator are generated according to the demands of the medical procedure and are administrable within the medium to the patient.

15

43. The system of claim 42 wherein said at least one pressurizing device includes at least one of a gear pump, a peristaltic pump, a syringe pump and a centrifugal pump.

20 44. The system of claim 42 wherein said controller controls at least one operating parameter of said pressurizing device and said bubble generator.

45. The system of claim 42 wherein said controller controls at least one operating parameter of said system based at least in part on feedback from an imaging unit used during the medical procedure.

25

46. The system of claim 42 wherein said controller includes a user interface for at least one of monitoring and changing at least one operating parameter of said system.

47. The system of claim 44, 45 or 46 wherein said operating parameters of said system include composition of the medium, composition of the bubbles in the medium, concentration of the bubbles in the medium, size of the bubbles in the medium, rate of flow of the medium, volume of the medium administered, timing of the administration of the medium, sequencing of the administration of the medium, pressure of the medium, and temperature of the medium.

48. The system of claim 42 further comprising a fluid verification device disposed between said bubble generator and the patient, said fluid verification device for at least one of monitoring and changing at least one operating parameter of said system.

49. The system of claim 48 wherein said fluid verification device is capable of at least one of (i) detecting an unacceptably large amount of gas and preventing administration thereof to the patient and (ii) destroying any of the bubbles having a diameter at least one of greater than, less than, within, and outside a predetermined range of sizes.

50. The system of claim 48 wherein said controller at least one of communicates with and controls operation of said fluid verification device.

51. The system of claim 48 wherein said controller controls operation of said system based at least in part on information from said fluid verification device.

52. The system of claim 42 wherein said bubble generator creates the bubbles by entraining the gas into a flow of the liquid to form the medium.

53. The system of claim 52 further comprising a fluid verification device disposed between said bubble generator and the patient, said fluid verification device for preventing administration of the medium upon at least one of a rate of flow of the medium dropping below a specified level and detecting that the medium contains an unacceptably large amount of gas.

54. The system of claim 42 wherein said bubble generator comprises:

- (a) an enclosure within which to agitate the first liquid in presence of the gas; and
- (b) a means for disrupting an interface between the first liquid and the gas, said disrupting means being responsive to a control signal from said controller by agitating said interface thereby creating the bubbles of the gas within the first liquid.

55. The system of claim 42 wherein said bubble generator comprises:

- (a) an enclosure within which to agitate the first liquid in presence of the gas;
- (b) a mechanism for agitating associated with said enclosure, said mechanism being responsive to a control signal from said controller by agitating an interface between the first liquid and the gas thereby creating the bubbles of the gas within the first liquid; and
- (c) a filter disposed proximate said outlet for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

56. The system of claim 42 wherein said bubble generator comprises:

- (a) an enclosure within which to place the first liquid in presence of the gas;

(b) two disks disposed in said enclosure, said disks separated by a gap of a preset thickness and capable of being spun;

(c) a mechanism for spinning said disks, said mechanism being responsive to a control signal from said controller by spinning said disks thereby compelling the first liquid to  
5 flow via into said gap resulting in creation of the bubbles of the gas within the first liquid; and

(d) a filter disposed proximate said outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

57. The system of claim 42 wherein said bubble generator comprises:

10 (a) an enclosure within which to place the first liquid in presence of the gas;

(b) a stirring element disposed in said enclosure;

(c) a mechanism for moving said stirring element, said mechanism being responsive to a control signal from said controller by moving said stirring element thereby causing the creation of the bubbles of the gas in the first liquid; and

15 (d) a filter disposed proximate said outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

58. The system of claim 57 wherein said stirring element comprises multiple small wires.

20

59. The system of claim 42 wherein the first liquid is supersaturated with the gas under pressure and has nucleation materials therein, with said bubble generator comprising a nozzle such that as the first liquid passes therethrough the pressure of the first liquid decreases causing the bubbles of the gas to form on the nucleation materials and come out of and entrain  
25 with the first liquid, thereby forming the medium.

60. The system of claim 59 wherein the nucleation materials comprise at least one of particles and chemicals.

5 61. The system of claim 42 wherein the first liquid is supersaturated with the gas under pressure as the first liquid enters said bubble generator, with said bubble generator comprising a nozzle having a plurality of nucleation sites formed therein such that as the first liquid passes through said nozzle and contacts at least one of said nucleation sites the pressure of the first liquid decreases causing the gas to come out of solution, forming bubbles that  
10 entrain with the first liquid thereby forming the medium.

62. The system of claim 61 wherein said nucleation sites take the form of pits formed in an inner wall of said nozzle.

15 63. The system of claim 61 wherein said nozzle is cylindrical in shape.

64. The system of claim 61 wherein said nozzle comprises plates attached together to form a pipe, with at least one of said plates bearing said nucleation sites.

20 65. The system of claim 42 wherein said bubble generator comprises:

(a) an enclosure within which to place the first liquid in which the gas is dissolved;  
and

(b) a device, controlled by said controller, to apply energy to the first liquid to create localized regions of gas supersaturation thereby enabling creation of the bubbles of the gas  
25 within the first liquid to form the medium.

66. The system of claim 65 wherein said localized regions of gas supersaturation comprise regions of reduced pressure created by at least one of mechanical motion, an oscillatory pressure component, and an oscillatory flow component.

5

67. The system of claim 42 wherein said bubble generator comprises:

(a) an enclosure within which to place the first liquid in which the gas is dissolved;  
and

(b) a transmitter for transmitting ultrasonic energy into the first liquid to cause  
10 cavitation therein thereby enabling creation of the bubbles of the gas within the first liquid to form the medium

68. The system of claim 42 wherein said bubble generator comprises:

(a) a liquid flow path for receiving and channeling the first liquid; and  
15 (b) a gas flow path for directing the gas to said liquid flow path;

with said liquid and said gas flow paths constituting a gas-liquid interface assembly such that said liquid flow path channels the first liquid to an intersection with said gas flow path to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.

20

69. The system of claim 68 wherein said controller operates said at least one pressurizing device and said source of the gas to produce an oscillatory component to the flow within at least one of the gas flowing in said gas flow path and the first liquid flowing in said liquid flow path to promote uniformity in a size of the bubbles.

25

70. The system of claim 68 wherein said bubble generator comprises an array of said gas-liquid interface assemblies.

71. The system of claim 68 wherein said bubble generator further comprises a fluid  
5 flow path for receiving and channeling the second liquid into the first liquid into which the gas has been entrained, thereby further forming the medium for communication from said outlet.

72. The system of claim 71 wherein said bubble generator comprises an array of said gas-liquid interfaces.

10

73. The system of claim 42 wherein said bubble generator comprises:

(a) a gas introduction plate having a plurality of gas inlets; and

(b) a liquid flow path for receiving and channeling the first liquid over said gas introduction plate to entrain as the bubbles the gas emanating from said gas inlets, thereby  
15 forming the medium for communication from said outlet.

74. The system of claim 73 wherein said controller operates said at least one pressurizing device and said source of the gas to produce an oscillatory component to the flow within at least one of the gas flowing in said gas inlets and the first liquid flowing in said liquid  
20 flow path.

75. The system of claim 73 wherein said bubble generator further comprises a secondary plate disposed a predetermined distance apart from said gas introduction plate between which the first liquid is channeled by said liquid flow path, said predetermined  
25 distance being selected to affect a size of the bubbles so entrained.



76. The system of claim 75 wherein said secondary plate has a plurality of gas inlets by which the gas is further so entrained by the first liquid flowing in said liquid flow path.

5 77. The system of claim 42 wherein said bubble generator comprises:

(a) a tube having a plurality of gas inlets defined through a wall thereof and one end for receiving the first liquid from said at least one pressurizing device, with said gas inlets adapted for receiving the gas from said at least one pressurizing device;

10 with said tube for channeling the first liquid over said gas inlets to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.

78. The system of claim 77 wherein said controller operates at least one of said at least one pressurizing device and said source of the gas to produce an oscillatory component to the flow of at least one of the first liquid and the gas.

79. The system of claim 42 wherein said bubble generator comprises:

(a) a chamber defining a plurality of gas inlets for receiving the gas from said at least one pressurizing device; and

20 (b) a liquid flow path defined within said chamber;

with said liquid flow path for channeling the first liquid to an intersection with said gas inlets to entrain the gas emanating therefrom as the bubbles, thereby forming the medium for communication from said outlet.

80. The system of claim 79 wherein said controller operates at least one of said at least one pressurizing device and said source of the gas to produce an oscillatory component to the flow of at least one of the first liquid and the gas.

5 81. The system of claim 42 wherein said bubble generator comprises:

(a) a first member having outer and inner sides with a plurality of inlet holes extending therebetween, said outer side of said first member for channeling the first liquid over said inlet holes;

10 (b) a second member having inner and outer sides with a plurality of outlet holes extending therebetween, said outer side of said second member for channeling the second liquid over said outlet holes, said inner sides of said first and said second members being separated by a gap and arranged so that each of said inlet holes aligns with one of said outlet holes, said gap for channeling the gas between said first and said second members; and

15 (c) a means for generating droplets of the first liquid such that each of said droplets is directed through one of said inlet holes, said outlet hole corresponding thereto and the gas present therebetween and into the second liquid thereby forming a bubble therefrom within the second liquid to form the medium therefrom.

82. The system of claim 42 wherein said bubble generator comprises:

20 (a) a housing having at least one cell chamber therein; and

(b) said at least one cell chamber defining therein a first liquid flow path, a second liquid flow path and a gas flow path, said first liquid flow path for receiving the first liquid, said second liquid flow path for receiving the second liquid, said gas flow path for receiving the gas;

25 wherein said gas flow path channels the gas received into an intersection of said flow paths at which the first and the second liquids meet so that, as a pulse of the second liquid arrives at said intersection, a bubble is (A) formed thereat from the second liquid and the gas

with the second liquid forming a shell of the bubble and (B) conveyed through said first liquid flow path into a flow of the first liquid outside of said cell chamber thereby forming the medium for communication from the outlet of said bubble generator.

5           83.     The system of claim 42 wherein said bubble generator comprises:

(a)     a plate having a first surface in contact with a first liquid and a second surface in contact with a second liquid with an inlet hole extending therebetween; and

(b)     a heater in communication with a wall of said inlet hole to form an interface assembly therefrom; such that, upon application of a pulse of energy to said heater, said heater  
10     heats the first liquid in said inlet hole to form a bubble of gas therefrom, the bubble moving from said interface assembly into the second liquid to form the medium therefrom.

84.     The system of claim 83 wherein the bubble incorporates components from the first liquid as it moves into the second liquid.

15

85.     The system of claim 84 wherein:

(a)     the first liquid is a hydrophobic liquid and the second liquid is hydrophilic liquid;

(b)     said first surface and said wall of said plate is hydrophobic and in contact with  
20     the hydrophobic liquid, with the hydrophobic liquid comprising a first fluid and a second fluid with the first fluid having a boiling point lower than the second fluid; and

(c)     said second surface is hydrophilic and in contact with the hydrophilic liquid;

such that, upon application of the pulse of energy to said heater, said heater heats the hydrophobic liquid in said inlet hole to form the bubble of gas from the first fluid thereof with

the second fluid thereof condensing and forming a shell of the bubble with the bubble moving from said interface assembly into the hydrophilic liquid to form the medium therefrom.

86. A bubble generating apparatus for creating bubbles on demand within a medium administrable to at least one patient for purposes of a medical procedure, said bubble generating apparatus comprising:

(a) at least one inlet for receiving at least one of a first liquid, a second liquid, and a gas;

(b) a generating mechanism to create the bubbles to form the medium therein from at least one of the first liquid, the second liquid, and the gas; and

(c) an outlet for conducting the medium to the at least one patient.

87. The bubble generating apparatus of claim 86 further comprising:

(a) a fluid monitor, in communication with said outlet, for controlling a property of the medium; and

(a) a controller for controlling operation of said fluid monitor and said generating mechanism so that the bubbles created thereby are generated according to the demands of the medical procedure.

88. The bubble generating apparatus of claim 86 further comprising:

(a) a medium delivery system for conducting the medium from said outlet for use of each of the at least one patient, said medium delivery system including:

(i) backflow prevention means for allowing flow in a forward direction while preventing flow in a backward direction, and

(ii) a medium path, said medium path including a first portion that is reusable for a plurality of the at least one patient and a second portion that is disposable, wherein a new disposable portion is used for each successive one of the at least one patient;

5 (c) said disposable portion comprising flow interrupting means to preclude cross-contamination of the medium flowing from said outlet; and

(d) wherein said reusable portion and said disposable portion cooperate to preclude flow of contaminants from any of the least one patient to said outlet, to said reusable portion of said medium delivery system, or to successive ones of the at least one patient.

10

89. The bubble generating apparatus of claim 86 further comprising:

(a) at least one reservoir for accommodating at least one of the first liquid, the second liquid and the gas; and

15 (b) at least one pressurizing device for conveying at least one of the first liquid, the second liquid, and the gas from said at least one reservoir to said generating mechanism and for moving the medium formed therein through said bubble generating apparatus.

90. The bubble generating apparatus of claim 89 further comprising:

20 (a) a fluid verification device for at least one of monitoring and changing at least one operating parameter of said bubble generating apparatus.

91. A bubble generator comprising:

(a) an enclosure within which to place a liquid in presence of a gas; and

25 (b) an agitating means for imparting energy to and disrupting an interface between the liquid and the gas to create bubbles of the gas within the liquid to form a medium therefrom.

92. The bubble generator of claim 91 wherein said agitating means is responsive to a control signal by agitating said enclosure thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

5

93. The bubble generator of claim 91 further comprising:

(a) a filter connected to an outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

10

94. The bubble generator of claim 91 wherein said agitating means comprises:

(a) two disks disposed in said enclosure, said disks separated by a gap of a preset thickness and capable of being spun; and

(b) a mechanism for spinning said disks, said mechanism being responsive to a control signal by spinning said disks thereby compelling the liquid to flow into said gap resulting in creation of the bubbles of the gas within the liquid to form the medium.

15

95. The bubble generator of claim 91 wherein said agitating means comprises:

(a) a stirring element disposed in said enclosure; and

(b) a mechanism for moving said stirring element, said mechanism being responsive to a control signal by moving said stirring element to impart energy to and disrupt the interface between the liquid and the gas thereby causing the creation of the bubbles of the gas in the liquid to form the medium.

20

96. The bubble generator of claim 95 wherein said stirring element comprises multiple small wires.

25

97. A bubble generator for use with a liquid supersaturated with gas under pressure and containing nucleation materials therein, said bubble generator comprising a nozzle such  
5 that as the liquid passes therethrough the pressure of the liquid decreases causing the bubbles of the gas to form on the nucleation materials and thus come out of and entrain with the liquid, thereby forming a medium.

98. The bubble generator of claim 97 wherein the nucleation materials comprise at  
10 least one of particles and chemicals.

99. A bubble generator for use with a liquid supersaturated with gas under pressure, said bubble generator comprising a nozzle having a plurality of nucleation sites formed therein such that as the liquid passes through said nozzle and contacts at least one of said nucleation  
15 sites the pressure of the liquid decreases causing bubbles of the gas to come out of and entrain with the liquid, thereby forming a medium.

100. The bubble generator of claim 99 wherein said nucleation sites take the form of  
pits formed in an inner wall of said nozzle.

101. The bubble generator of claim 99 wherein said nozzle is cylindrical in shape.

102. The bubble generator of claim 99 wherein said nozzle comprises plates attached together to form a pipe, with at least one of said plates bearing said nucleation sites.

103. A bubble generator comprising:

- (a) an enclosure within which to place a liquid in which a gas is dissolved; and
- (b) an agitating means for causing cavitation within the liquid to create bubbles of the gas within the liquid to form a medium therefrom.

5           104. The bubble generator of claim 103 wherein said agitating means is responsive to a control signal by creating a region of low pressure within the liquid thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

10           105. The bubble generator of claim 103 further comprising a filter connected to an outlet of said enclosure for removing from the medium any of the bubbles having a diameter greater than a predetermined size.

          106. The bubble generator of claim 103 wherein said agitating means comprises:

- (a) at least one disk submerged in the liquid; and
- 15       (b) a mechanism for spinning said at least one disk, said mechanism being responsive to a control signal by spinning said at least one disk to create a region of low pressure within the liquid thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

20           107. The bubble generator of claim 106 wherein:

- (a) said at least one disk has two disks in the liquid, said disks separated by a gap of a preset thickness and capable of being spun in opposite directions; and
- (b) said mechanism for spinning said disks being responsive to the control signal by spinning said disks in opposite directions thereby creating the region of low pressure within the  
25 liquid and enabling the creation of the bubbles of the gas within the liquid to form the medium.



108. The bubble generator of claim 103 wherein said agitating means comprises:

(a) a stirring element submerged in the liquid; and

(b) a mechanism for moving said stirring element, said mechanism being responsive

5 to a control signal by moving said spinning element to create a region of low pressure within the liquid thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

109. The bubble generator of claim 103 wherein said agitating means comprises a

10 transmitter for transmitting ultrasonic energy into the liquid to create a region of low pressure therein thereby enabling creation of the bubbles of the gas within the liquid to form the medium.

110. The bubble generator of claim 109 wherein the liquid contains nucleation

15 materials therein to facilitate the creation of the bubbles within the liquid.

111. The bubble generator of claim 109 wherein a surface in said enclosure has a

plurality of nucleation sites to facilitate the creation of the bubbles within the liquid.

20 112. A bubble generator comprising:

(a) a first liquid flow path for receiving a liquid from a pressurizing device; and

(b) a gas flow path for communication with a source of gas for directing the gas received therefrom to said liquid flow path;

with said liquid and said gas flow paths constituting a gas-liquid interface assembly

25 such that said liquid flow path channels the liquid received from said pressurizing device to an

intersection with said gas flow path to entrain the gas emanating therefrom as bubbles in the liquid, thereby forming a medium for communication from an outlet of said bubble generator.

113. The bubble generator of claim 112 comprising an array of said gas-liquid  
5 interface assemblies.

114. The bubble generator of claim 112 further comprising a second liquid flow path for receiving a second liquid from said pressurizing device and for channeling the second liquid received therefrom into the liquid into which the gas has been entrained, thereby further  
10 forming the medium for communication from said outlet.

115. The bubble generator of claim 114 comprising an array of said gas-liquid interface assemblies.

15 116. A bubble generator comprising:

(a) a gas introduction plate having a plurality of gas inlets in communication with a source of gas; and

(b) a liquid flow path for receiving a liquid from a pressurizing device and for channeling the liquid received therefrom over said gas introduction plate to entrain as bubbles  
20 the gas emanating from said gas inlets, thereby forming a medium for communication from a outlet of said bubble generator.

117. The bubble generator of claim 116 further comprising:

(a) a secondary plate disposed a predetermined distance apart from said gas introduction plate between which the liquid is channeled by said liquid flow path, said predetermined distance being selected to affect a size of the bubbles so entrained.

5            118. The bubble generator of claim 117 wherein said secondary plate has a plurality of gas inlets by which the gas is further so entrained by the liquid flowing in said liquid flow path.

119. A bubble generator comprising:

10            (a) a tube having a plurality of gas inlets defined through a wall thereof and one end for receiving a liquid due to a pressurizing device, said gas inlets adapted for communication with a source of gas;

with said tube for channeling the liquid over said gas inlets to entrain the gas emanating therefrom as bubbles, thereby forming a medium for communication from an outlet of said  
15 bubble generator.

120. The bubble generator of claim 119 further comprising a spiral vane connected to said tube on an upstream side thereof.

20            121. A bubble generator comprising:

(a) a chamber defining a liquid flow path therein; and

(b) a plurality of gas inlets defined in a wall of said liquid flow path, each of said gas inlets for receiving a gas from a source thereof;

with said liquid flow path for channeling the liquid received from said pressurizing  
25 device to an intersection with said gas inlets so that the gas emanating therefrom is entrained as

bubbles in said liquid, thereby forming the medium for communication from an outlet of said bubble generator.

122. A bubble generator comprising:

5 (a) a first plate having outer and inner sides with a plurality of inlet holes extending therebetween, said outer side of said first plate for channeling a first liquid over said inlet holes;

(b) a second plate having inner and outer sides with a plurality of outlet holes extending therebetween, said outer side of said second plate for channeling a second liquid over said outlet holes, said inner sides of said first and said second plates being separated by a gap  
10 and arranged so that each of said inlet holes aligns with one of said outlet holes, said gap for channeling a gas between said first and said second plates; and

(c) a means for generating droplets of said first liquid such that each of said droplets is directed through one of said inlet holes, said outlet hole corresponding thereto and said gas present therebetween and into said second liquid thereby forming a bubble therefrom within  
15 said second liquid.

123. The bubble generator of claim 122 wherein at least one of said inner sides of said first and said second plates is hydrophobic.

20 124. The bubble generator of claim 122 wherein said outer side of said second plate is hydrophilic.

125. The bubble generator of claim 122 wherein said first liquid is hydrophobic and said second liquid is hydrophilic.

25

126. The bubble generator of claim 122 wherein said second liquid contains a surfactant.

127. A bubble generator comprising:

5 (a) a housing having at least one cell chamber therein; and

(b) said at least one cell chamber defining therein a first liquid flow path, a second liquid flow path and a gas flow path, said first liquid flow path for receiving a first liquid from a first pressurizing device, said second liquid flow path for receiving a second liquid from a second pressurizing device, said gas flow path for receiving a gas from a third pressuring  
10 device;

wherein said gas flow path channels the gas received from said third pressurizing device into an intersection of said flow paths at which the first and the second liquids meet so that, as a pulse of the second liquid arrives at said intersection, a bubble is (A) formed thereat from the second liquid and the gas with the second liquid forming a shell of the bubble and (B) conveyed  
15 through said first liquid flow path into a flow of the first liquid outside of said cell chamber thereby forming a medium for communication from an outlet of said bubble generator.

128. The bubble generator of claim 127 wherein said at least one cell chamber comprises an array of said cell chambers.

129. The bubble generator of claim 127 wherein said first liquid and said second liquid are one of (i) hydrophilic and hydrophobic, respectively; (ii) hydrophobic and hydrophilic, respectively; (iii) both hydrophilic; and (iv) both hydrophobic.

130. A bubble generator comprising:

(a) a plate having a first surface in contact with a first liquid and a second surface in contact with a second liquid with an inlet hole extending therebetween; and

(b) a heater in communication with a wall of said inlet hole to form an interface assembly therefrom; such that, upon application of a pulse of energy to said heater, said heater heats the first liquid in said inlet hole to form a bubble of gas therefrom, the bubble moving from said interface assembly into the second liquid to form the medium therefrom.

131. The bubble generator of claim 130 wherein the bubble incorporates components from the first liquid as it moves into the second liquid.

132. The bubble generator of claim 131 wherein:

(a) the first liquid is a hydrophobic liquid and the second liquid is hydrophilic liquid;

(b) said first surface and said wall of said plate is hydrophobic and in contact with the hydrophobic liquid, with the hydrophobic liquid comprising a first fluid and a second fluid with the first fluid having a boiling point lower than the second fluid; and

(c) said second surface is hydrophilic and in contact with the hydrophilic liquid;

such that, upon application of the pulse of energy to said heater, said heater heats the hydrophobic liquid in said inlet hole to form the bubble of gas from the first fluid thereof with the second fluid thereof condensing and forming a shell of the bubble with the bubble moving from said interface assembly into the hydrophilic liquid to form the medium therefrom.

133. The bubble generator of claim 130 comprising an array of said interface assemblies.

134. A method of generating a medium of bubbles on demand for administration to a patient for purposes of a medical procedure, said method comprising the steps of:

(a) providing a source of at least one of a first liquid, a second liquid and a gas;

(b) generating the bubbles using at least one of the first liquid, the second liquid, and  
5 the gas and creating the medium therewith; and

(c) controlling generation of the bubbles so that the bubbles are generated according to the demands of the medical procedure and are administrable within the medium to the patient.

10 135. The method of claim 134 wherein the step of controlling generation of the bubbles includes using feedback from an imaging unit used during the medical procedure.

136. The method of claim 134 wherein the step of controlling generation of the bubbles includes monitoring and optionally changing at least one operating parameter of said  
15 method.

137. The method of claim 136 wherein said operating parameters include composition of the medium, composition of the bubbles in the medium, concentration of the bubbles in the medium, size of the bubbles in the medium, rate of flow of the medium, volume of the medium  
20 administered, timing of the administration of the medium, sequencing of the administration of the medium, pressure of the medium, and temperature of the medium.

138. The method of claim 134 wherein the step of controlling generation of the bubbles includes a capability of at least one of (i) detecting an unacceptably large amount of gas  
25 in a flow of the medium and preventing administration thereof to the patient and (ii) destroying

any of the bubbles having a diameter at least one of greater than, less than, within, and outside a predetermined range of sizes.

139. The method of claim 134 wherein the step of controlling generation of the bubbles includes preventing administration of the medium upon at least one of a rate of flow of the medium dropping below a specified level and detecting that the medium contains an unacceptably large amount of gas.

140. A system for creating a plurality of differentiable populations of bubbles of gas for use within a medium administrable to a patient for purposes of a medical procedure, said system comprising:

- (a) at least one reservoir for accommodating at least one of a liquid and the gas;
- (b) at least one pressurizing device for conveying at least one of the liquid and the gas, and the medium formed therewith, through said system; and
- (c) at least one bubble generator having at least one inlet for receiving the liquid and the gas and creating therefrom said plurality of differentiable populations of bubbles, said at least one bubble generator having at least one outlet for communication of the medium, and said plurality of differentiable populations of bubbles therein, to the patient.

141. The system of claim 140 further comprising a controller for controlling operation of said system so that said plurality of differentiable populations of bubbles created by said at least one bubble generator are generated according to the demands of the medical procedure and are administrable within the medium to the patient.

142. The system of claim 141 wherein said controller controls at least one operating parameter of said at least one bubble generator.



143. The system of claim 142 wherein said operating parameters include composition of the medium, composition of the bubbles in the medium, concentration of the bubbles in the medium, size of the bubbles in the medium, rate of flow of the medium, volume of the medium administered, timing of the administration of the medium, sequencing of the administration of the medium, pressure of the medium, and temperature of the medium.